Claims

1. A method of determining channel impulse responses of a plurality of channels to a communication device, the method comprising:

performing transform operations on both a replica of a signal sequence s_n and a received training sequence y_n received by the communication device in at least one burst, the received training sequence y_n being the signal sequence as received through a channel, the transform operations arranged to generate a multiplicity of signal sequence frequency bins and a multiplicity of training sequence frequency bins;

performing point-by-point operations between corresponding signal sequence frequency bins and training sequence frequency bins; and

concatenating the point-by-point operations associated with the channel to provide a composite frequency response for the channel, the composite frequency response allowing, in the time domain, generation of the channel impulse response for the channel.

2. The method according to claim 1, further comprising:

separating training sequence bursts emanating from a single element transmitter by one of a cyclic prefix and a blank (zero) carrier.

3. The method according to claim 1, wherein multiple Steiner codes are transmitted as training sequences, the multiple Steiner codes sent from multiple transmit elements in multiple training bursts.

4. The method according to claim 3, wherein the multiple Steiner codes are transmitted from multiple elements of a base station transmit antenna.

5. The method according to claim 1, further comprising using a set of matrix operations in the frequency domain to resolve channels to the communication device from multiple transmitting stations, the matrix operations providing solvable linear equations for the channel impulse response H and the signal

sequence S expressible in a matrix-vector form at each frequency bin in terms of the received training sequence Y.

6. The method according to claim 5, further comprising solving the linear equations using a minimum mean square error (MMSE) estimation technique.

7. The method according to claim 6, wherein the MMSE estimation technique employs a Weiner filtering operation providing:

$$\hat{H} = \left(S^H S + \mathrm{Cov}(B)\right)^{-1} S^H Y$$

where: *Cov(B)* is a covariance matrix of thermal noise;

$S^H Y$ is a matched filter operation arranged to minimize the signal to noise ratio but not to remove mutual interference between channel estimates; and

$(S^H S + Cov(B))^{-1}$ is a decoupling matric that removes the coupling between different channels caused by any non-ideal nature of the training sequences.

8. The method according to claim 2, wherein the number of bursts sent to the communication device from each transmitting unit in communication contact therewith is calculated as a multiplication of:

a number of transmitting elements in a transmit array of a transmitting unit; and

a number of transmitting units in communication contact with the communication device.

9. The method according to claim 8, wherein training sequence burst between transmitting units are time-aligned.

10. A method of determining channel impulse responses of channels incident to a communication device, the method comprising: and

transmitting multiple quasi-orthogonal pseudo-noise sequences as bursts from multiple base stations each having at least one transmit element, successive bursts providing an extended training sequence for use in channel estimation at the communication device;

applying a Wiener frequency domain MMSE deconvolution with frequency domain spatial decoupling matrices to generate channel impulse response estimates for the channels.

11. The method according to claim 10, wherein the quasi-orthogonal pseudo-noise sequences are Steiner codes.

12. The method according to claim 11, further comprising allocating only a single training sequence to each base station, the single training sequence being of sufficient length to encompass all multiple time-translated channel impulse responses.

13. A communication device operational to receive a plurality of training sequences on a plurality of channels, the communication device comprising:

14. A method of determining channel impulse responses of a plurality of channels established between a plurality of transmitting elements and a communication device in a communication system, the method comprising:

substantially simultaneously transmitting different training bursts from each of the plurality of transmitting elements, each burst having a length at least as long as a maximum channel duration in the communication system multiplied by a number corresponding to the plurality of transmitting elements;

recovering at the communication device a signal sequence y_n from the different training bursts s_n; and

resolving the plurality of channels to recover associated channel impulse responses H for each channel by solving an algebraic matrix operation expressed in matrix-vector form as $Y=SH$, where: S is a matrix of partial training bursts for each channel, each training burst segmented into N pieces in the time

domain; Y is a vector of a received signal sequence; and H is a concatenation of different channel impulse response vectors.

15. A computer program product for a processor within a receiver device, the computer program product comprising:

code that performs transform operations on both a replica of a signal sequence s_n and a received training sequence y_n received by the communication device in at least one burst, the received training sequence y_n being the signal sequence as received through a channel, the transform operations arranged to generate a multiplicity of signal sequence frequency bins and a multiplicity of training sequence frequency bins;

code that performs point-by-point operations between corresponding signal sequence frequency bins and training sequence frequency bins; and

code that concatenates the point-by-point operations associated with the channel to provide a composite frequency response for the channel, the composite frequency response allowing, in the time domain, generation of the channel impulse response for the channel;

wherein the codes reside in a computer readable medium.

16. A communication device having a receiver coupled, in use, to receive a plurality of channels supporting a signal sequence y_n and training sequence bursts, the communication device having:

a signal processing platform to perform transform operations on both a replica of a signal sequence s_n and a received training sequence y_n received by the communication device in at least one burst, the received training sequence y_n being the signal sequence as received through a channel, the transform operations arranged to generate a multiplicity of signal sequence frequency bins and a multiplicity of training sequence frequency bins;

the signal processing platform arranged to perform point-by-point operations between corresponding signal sequence frequency bins and training sequence frequency bins; and

the signal processing platform further arranged to concatenate the point-by-point operations associated with the channel to provide a composite frequency response for the channel, the composite frequency response allowing, in the time domain, generation of the channel impulse response for the channel.

17. The communication device according to claim 16, wherein multiple Steiner codes are transmitted as the training sequences, the multiple Steiner codes sent to the receiver through multiple channels in multiple training bursts.

18. The communication device according to claim 16, wherein the signal processing platform operates to establish a set of matrix operations in the frequency domain to resolve channels to the communication device from multiple transmitting stations, the matrix operations providing solvable linear equations for the channel impulse response *H* and the training sequence *S* expressible in a matrix-vector form at each frequency bin.

19. The communication device according to claim 18, wherein the signal processing platform solves the linear equations using a minimum mean square error (MMSE) estimation technique.

20. The communication device according to claim 19, wherein the MMSE estimation technique employs a Weiner filtering operation providing:

$$\hat{H} = \left(S^H S + \mathrm{Cov}(B)\right)^{-1} S^H Y$$

where: *Cov(B)* is a covariance matrix of thermal noise;

$S^H Y$ is a matched filter operation arranged to minimize the signal to noise ratio but not to remove mutual interference between channel estimates; and

$(S^H S + Cov(B))^{-1}$ is a decoupling matric that removes the coupling between different channels caused by any non-ideal nature of the training sequences.

21. A communication receiver comprising:

means for receiving, in use, multiple quasi-orthogonal pseudo-noise sequences as bursts from multiple base stations each having at least one transmit element, successive bursts providing an extended training sequence for use in channel estimation at the communication receiver; and

means for applying a Wiener frequency domain MMSE deconvolution with frequency domain spatial decoupling matrices to generate channel impulse response estimates for the channels.

22. The communication receiver of claim 21, wherein the quasi-orthogonal pseudo-noise sequences are Steiner codes.

23. A communication device operational to receive a plurality of training sequences on a plurality of channels and a signal sequence y_n, the communication device comprising:

a receiver for substantially simultaneously receiving, in use, different training bursts from each of the plurality of channels emanating from a plurality of transmit elements, each burst having a length at least as long as a maximum channel duration multiplied by a number corresponding to the plurality of transmit elements;

recovery circuitry for recovering, in use, the signal sequence y_n from the different training bursts s_n; and

a processor arranged to resolve the plurality of channels to recover associated channel impulse responses H for each channel by solving an algebraic matrix operation expressed in matrix-vector form as $Y=SH$, where: S is a matrix of partial training bursts for each channel, each training burst segmented into N pieces in the time domain; Y is a vector of a received signal sequence; and H is a concatenation of different channel impulse response vectors.

24. A base station of a communication system, the base station comprising:

a transmitter chain arranged to transmit multiple quasi-orthogonal pseudo-noise sequences as training bursts s_n from at least one transmit element and further arranged to transmit a signal sequence y_n, successive training bursts providing an extended training sequence for use in channel estimation at a communication device of the communication system, the transmitter chain substantially simultaneously transmitting, in use, different training bursts from each of the at least one transmit element, each training burst having a length at least as long as a maximum channel duration in the communication system multiplied by a number corresponding to a plurality of channels to the communication device, the extended training sequence and the signal sequence y_n providing a resolution mechanism to the communication device allowing the communication device to resolving the plurality of channels to recover associated channel impulse responses H for each channel by solving an algebraic matrix operation expressed in matrix-vector form as $Y=SH$, where: S is a matrix of partial training bursts for each channel, each training burst segmented into N pieces in the time domain; Y is a vector of a received signal sequence; and H is a concatenation of different channel impulse response vectors.

25. The base station of claim 24, wherein the transmit chain is further arranged to separate training bursts emanating from the at least one transmit element by one of a cyclic prefix and a blank (zero) carrier.

26. The base station of claim 24, wherein multiple Steiner codes are transmitted as training bursts, the multiple Steiner codes sent from multiple transmit elements in multiple training bursts.

27. The base station of claim 24, wherein the number of training bursts sent to the communication device from each base station in communication contact therewith is calculated as a multiplication of:

a number of transmitting elements in a transmit array of a base station; and

a number of base stations in communication contact with the communication device.